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FIBER REINFORCED EPOXY RESIN PRODUCT AND METHOD FOR THE
MANUFACTURE THEREOF

This application is a Continuation Application of PCT
5 International Application No. PCT/KR00/00403 filed on April
28, 2000, which designated the United States.

Field of the Invention

10 *Summary*
The present invention relates to a fiber reinforced
epoxy resin product and a method for manufacturing thereof;
more particularly, to a fiber reinforced epoxy resin product
comprising a hardened epoxy resin mixture including epoxy
resin, silica and reinforcing fiber materials such as glass
15 fiber, carbon fiber, aramid fiber or Kevlar fiber, and at
least one layer of fiber glass roving cloth and a method for
manufacturing thereof.

Background of the Invention

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Conventionally, various methods such as a steel plate
bonding method, prestressing method and cross section
increasing method are used for reinforcing and repairing a
concrete structure.

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The steel plate bonding method is adopted for
reinforcing bending strength of decks or shear strength of

piers of a bridge. The prestressing method is used with concrete casting when the amount of prestress is less than a desired level. The cross section increasing method is applied when the amount of reinforcing rods and the cross
5 section of the concrete structure is insufficient.

Recently, the steel plate bonding method is most widely used among above-mentioned methods. In this method, steel plates are bonded to concrete surfaces via adhesive material such as epoxy resin in order to assure the
10 transmission of shear stress and sufficient adhere strength between the concrete surfaces and the steel plates.

In such a method, however, continuous maintenance is needed to keep the sufficient adhere strength between the concrete surfaces and steel plates. And, where the concrete
15 structure is exposed to seawater, it is difficult to achieve sufficient reinforcement or repair because of corrosion of the steel plates or problems related to durability of adhesive material. Also, the structural load increases as the number of the steel plates increases, wherein steel has
20 a relatively high specific weight. Further, the steel plates are usually bonded to a bottom surface of the structure. Thus, lots of working hours and workers are needed, thereby increasing the costs.

By utilizing fiber reinforced plastics (FRP) panels
25 instead of steel plates, the problems caused by corrosion can be prevented. However, FRP panels have such a low

strength that they function just as a cover for concrete surfaces.

In order to solve these problems, there have been suggested several improved methods such as those described in Korean Laid-open Publication No. 174,161 having the title of "A epoxy resin panel for reinforcing concrete structure and a method for the manufacture thereof" filed by the applicant or Japanese Laid-open Publication No. 4-67946 having the title of "Thermosetting resin composite panel".

The resin panels suggested by these methods include metal wires as a reinforcing material. However, the metal wires are corroded after a long period of use, which makes the binding strength between resin material and wires decreased and, in turn, cracks or delamination is developed in the resin panels. Further, weatherability and chemical resistance of the metal wires are not sufficient and, most of all, physical properties such as tension strength or compressive strength are deteriorated by the weakened binding strength.

Summary of the Invention

It is, therefore, an object of the present invention to provide a fiber reinforced epoxy resin product having improved physical and chemical properties and also having better weatherability and chemical resistance by mixing

epoxy resin with fiber chops and casting the mixture into a mold in which at least one layer of glass fiber roving cloth is arranged. It is another object of the present invention to provide a method for manufacturing such a fiber reinforced epoxy resin product.

A fiber reinforced epoxy resin panel according to the present invention can be used in various fields such as, for example, 1) reinforcement and repair of various kinds of concrete structures, 2) protection of surfaces of concrete structures from seawater, foul water, damages by freeze-thaw or other chemical actions, 3) reinforcement of tunnel linings, 4) corner casting panels for container terminal, 5) vehicle block, or the likes.

In accordance with a preferred embodiment of the present invention, there is provided a method for manufacturing a fiber reinforced epoxy resin product, comprising the steps of providing a mold for the product; applying a release agent to inner surfaces of the mold; providing at least one layer of glass fiber roving cloth in the mold; casting an unhardened epoxy resin mixture in the mold; pressing the epoxy resin mixture in the mold; hardening the epoxy resin mixture in the mold under a temperature between about 20°C and about 80°C for more than 30 minutes; releasing the hardened epoxy resin mixture from the mold; and curing the hardened epoxy resin mixture under a temperature between about 20°C and 35°C for about 24 hours

to form the product.

In accordance with another preferred embodiment of the present invention, there is provided a fiber reinforced epoxy resin product, comprising a hardened epoxy resin mixture including epoxy resin, silica and a fibrous material, wherein the fibrous material is a material selected from the group consisting of glass fiber, carbon fiber, aramid fiber and Kevlar fiber or a mixture thereof; and at least one layer of glass fiber roving cloth is arranged parallel to each other in the hardened epoxy resin mixture.

Brief Description of the Drawings

The above and other objects and features of the present invention will become apparent from the following description of preferred embodiments given in conjunction with the accompanying drawings, in which:

Fig. 1A to 1F show an exemplified process of manufacturing the fiber reinforced epoxy resin product in accordance with the present invention;

Fig. 2 illustrates a cross-sectional view of a fiber reinforced epoxy resin panel manufactured in accordance with the method of the present invention;

Fig. 3 describes a cross-sectional view of a fiber reinforced epoxy resin panel bonded to a surface of a concrete structure for reinforcing in accordance with the

present invention;

Fig. 4A represents a plan view of a corner casting panel as an application of the fiber reinforced epoxy resin product in accordance with the present invention;

Fig. 4B is a side view of the corner casting panel shown in Fig. 4A;

Fig. 4C offers the installation of the panel in accordance with the present invention;

Fig. 5A to 5C provides vehicle blocks manufactured by the method in accordance with the present invention;

Fig. 6 sets forth an elevation view of the installed vehicle blocks; and,

Fig. 7 portrays a cross-sectional view taken along line I-I in Fig. 6.

Detailed Description of the Preferred Embodiments

Fig. 1A to Fig. 1F illustrate an exemplified process of manufacturing a fiber reinforced epoxy resin product in accordance with the present invention.

Step (a): a rectangular-shape mold (10) having a predetermined size is provided and dirt or other unnecessary materials are removed therefrom. The mold (10) can have various sizes and shapes depending on the use of a finished product. Preferably, the mold (10) is made of metal for durability and can be utilized again after cleaning inner

surfaces thereof.

Step (b): a release agent (20) of conventional type is coated to inner surfaces of the mold (10) with a constant thickness. The release agent (20) facilitates the separation of the finished product from the mold.

Step (c): a first fiber mesh (30A) having meshes of predetermined sizes is allocated above the release agent (20) in the mold (10). Before this, the first fiber mesh (30A) is cut into a suitable size to fit in the mold and may be impregnated with epoxy resin in order to enhance the strength. Preferably, the epoxy resin has physical properties as followings: less than or equal to 380 mPas (380 csp) of viscosity, about 15 minutes of gel time, more than or equal to 1000 kg/cm² of compressive strength, more than or equal to 500 kg/cm² of bending strength, more than or equal to 800 kg/cm² of shear strength, more than or equal to 130 kg/cm² of adhesive strength, more than or equal to 0.02 of tensile fracture strain rate; 1.0×10^{-5} to 2.0×10^{-5} cm/cm/°C of coefficient of expansion; 50 to 75°C of heat deflection degree.

Step (d): Epoxy resin is mixed with reinforcing fiber materials in a ratio of 9 to 1 and the mixture is cast onto the first fiber mesh (30A) which was impregnated with the epoxy resin (a first casting process). The mixture includes the epoxy resin, a small amount of cement, silica and chopped reinforcing fiber material. The reinforcing fiber

material is a material selected from the group consisting of glass fiber, carbon fiber, agamid fiber and Kevlar fiber or the mixture thereof.

Preferably, the epoxy resin has following properties:

5 1.15 to 1.20 of specific weight; M70 to M80 of hardness; 19,000 to 24,000 cps of viscosity; less than or equal to 0.14% of absorptivity; less than or equal to 1.1% of shrinkage; and 180 to 230 of epoxy equivalent. The preferable properties of the silica are as followings: more

10 than or equal to 95% of purity; 2.25 to 2.65 of specific weight; 6.5 to 7.0 of Mohs hardness and 7 to 9 pH.

Step (e): After the first casting process, a second fiber mesh (30B) having same size and shape with the first fiber mesh (30A) is allocated in the mold and the epoxy

15 resin mixture is cast thereon (a second casting process). When the second casting process is finished, a third fiber mesh (30C) is allocated parallel to the first and second fiber mesh (30A, 30B) in the mold. The number of fiber mesh layers may be varied depending on the use of a finished

20 epoxy resin product. When it is used for reinforcement and repair of concrete structures, the finished epoxy resin product preferably has a plurality of layers and, e.g., the number of layers and the amount of the fibers are decided according to desired strength increase which may be

25 calculated by structural analysis.

When the first and second casting process is finished,

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vibrations are applied to the mold (10) by a vibrator such that the fiber meshes are moved into the epoxy resin mixture as shown in Fig. 1E.

5 After the vibrating process, the epoxy resin mixture is hardened under a temperature of 60°C for 30 minutes, and then pressed with a load of 1000 kg. Next, the epoxy resin mixture is hardened at a temperature of 80C for 3 hours.

10 Step (f): The hardened epoxy resin mixture is released from the mold (10) and cured under a temperature between 25 to 30°C for a predetermined period to form a fiber reinforced epoxy resin product (1). The mold (10) can be used again after the dirt is removed therefrom.

15 Fig. 2 shows a cross-sectional view of a fiber reinforced epoxy resin panel manufactured in accordance with the method of the present invention.

Fig. 3 is a cross-sectional view of a fiber reinforced epoxy resin panel bonded to a surface of a concrete structure for reinforcing.

20 First, a surface of a concrete structure (80) is pretreated for the reinforcement. A surface area to be reinforced and repaired is determined and the compression strength of the concrete structure is measured. The size of reinforcing panel is determined depending on the desired strength. Deteriorated parts of the concrete structure are removed and the surfaces are pretreated. Corroded steel
25 reinforcing bars are repaired if required.

Next, the fiber reinforced epoxy resin panel (1) is fixed to the surface of concrete structure (80) via an anchor bolt or a chemical anchor bolt (84). The epoxy resin panel (1) is anchored to the surface with a gap of about 2 to about 6 mm by means of spacers. Adhesive epoxy resin will be injected into the gap between the panel and the surface. It is preferable that the gap between the panel and surface is as small as possible. Heads of the anchor bolts (84) are removed or covered by anchor caps to prevent corrosion. It is preferable that a distance from the anchor bolt (84) to the edge of the panel does not exceed 100 mm and a length of the anchor bolt is at least 2 to 3 times a depth of deteriorated parts. About 9 bolts are installed per 1 m² and generally a distance between the bolts is 30 cm.

Thereafter, adhesive epoxy resin (90) is injected into the gap. Before the injection, peripheries of the panel (1) are sealed with a sealant which is preferably the same type as the adhesive epoxy resin. Preferably, the adhesive epoxy resin (90) has same properties as the epoxy resin constituting the epoxy resin mixture but has lower viscosity. It is preferable to examine the properties of the adhesive epoxy resin (90) and working condition by mock-up test. The adhesive epoxy resin (90) is injected into the gap by an injection pressure of, e.g., 0.5 to 2.5 kg/cm². Injection process starts at a low pressure and the pressure is slowly increased in order to prevent the generation of air bubbles.

This process is performed at a temperature of 5 to 30°C.

After the injection process is finished, the adhesive epoxy resin is cured for 3 days. The epoxy resin panels are protected from rainwater or dirt by covering it with vinyl sheet or the like. Heads of anchor bolts can be removed for good appearance.

Fig. 4A shows a plan view of a corner casting panel as an application of the fiber reinforced epoxy resin product in accordance with the present invention. Also, Fig. 4B is a side view thereof and Fig. 4C shows the installation of the panel.

A corner casting panel (100) is an article for protecting surfaces (110) of container terminal from being damaged by corner portions of container boxes. These panels (100) are arranged to support the corners of the container boxes.

These corner casting panels are manufactured by the same process as above described except that more fiber mesh layers are included and compositions of some components are different in order to increase the strength. The panels can be manufactured in various sizes such as, e.g., {420 mm X 1350 mm X 20 mm}, {420 mm X 600 mm X 20 mm} or {1000 mm X 1350 mm X 20 mm}.

Figs. 5A to 5C show vehicle blocks manufactured by the method in accordance with the present invention.

These vehicle blocks (200, 200A, 200B) are

manufactured by the same process as above described in various sizes. The vehicle blocks (200, 200A, 200B) have through holes (212) for fixing bolts (210). Preferably, the fixing bolts (210) are more than 2 times longer than the heights of the blocks (200, 200A, 200B). The numbers of the through holes (212) can be changed depending on the length of the block.

Fig. 6 is an elevation view of the installed vehicle blocks. Fig. 7 shows a cross-sectional view taken along line I-I in Fig. 6.

These vehicle blocks are manufactured by the same process as above described except that the epoxy resin mixture preferably has compositions as followings: 10 to 30 wt% of epoxy resin, 20 to 39 wt% of silica, 30 to 68 wt% of rubbles and 0.01 to 1 wt% of reinforcing materials, and more preferably, 13.64 wt% of epoxy resin, 39.59 wt% of silica, 46.70 wt% of rubbles and 0.07 wt% of reinforcing fiber materials.

Preferably, the fiber mesh has properties as followings: 550 to 610 g/m² of weight, more than or equal to 6.3 of density, more than or equal to 1,500 kg/mm² of tensile strength and more than or equal to 1,295 kg/mm² of bending strength.

Also, the epoxy resin mixture may include inorganic materials having refractory and self-extinguishing characteristics, e.g., aluminum hydroxide, antimony oxide or

hydro bromide. In order to maintain the structural strength, it is preferable that the epoxy resin mixture does not include the inorganic materials more than 5 wt% relative to the total weight of the epoxy resin mixture.

5 As shown in the drawings, the vehicle blocks (200, 200C) are aligned in a predetermined interval. The interval is corresponding to a width of vehicles and the vehicle blocks (200B) having inclined surface are allocated at both ends of the vehicle block line.

10 The vehicle blocks (200) are fixed to desired places with the bolts (210) after surfaces (300) of the places are cleaned. Next, peripheries of each block are sealed by sealant and then resin inlet and air outlet are formed. Thereafter, adhesive epoxy resin (220) is injected into an
15 interface between the surface and the block for preventing permeation of water and assuring that the blocks are firmly fixed to the surfaces. Preferably, an adhesive epoxy resin layer has a thickness of about 2 mm to 6 mm. Injection process starts at a lower pressure which is increased to
20 higher pressure gradually and slowly in order to prevent generation of air bubbles. It is preferably that the injection pressure is 0.5 to 2.5 kg/cm². The adhesive epoxy resin has the same properties as above described except that it has lower viscosity and a gel time of about 3 hours.

25 After the injection process, the adhesive epoxy resin is cured more than 3 hours. An epoxy based paint may be

applied to the surface of the vehicle block. Above described process also can be applied to manufacture the corner casting panels.

5 Examples

Examples of manufacturing the concrete reinforcing panels and vehicle blocks are described hereinafter.

Example 1

10 A mold having a size of 1000 mm X 1000 mm X 11 mm was prepared. A release agent was applied to inner surfaces of the mold. At least three layers of fiber mesh were arranged in the mold. Thereafter, an epoxy resin mixture including 30.1 wt% of epoxy resin, 0.5 wt% of cement, 69.3 wt% of
15 silica and 0.1 wt% of chopped fibers was cast into the mold and then the mold was vibrated. After hardening process at a temperature of 60°C for 30 minutes, the epoxy resin mixture was pressurized with a load of 1,000 kg. The epoxy resin mixture was further hardened at a temperature of 80°C
20 for 3 hours and then released from the mold. The hardened epoxy resin mixture was cured at a temperature of 25 to 30°C and a humidity of 40 to 50% for 3 days. Properties of finished epoxy resin panels were tested and a result obtained is as followings:

25

TABLE 1

Mechanical properties		Test result	Remarks
Compression strength (kg/cm ²)		800	fracture strain rate 0.017
Direct tensile strength (kg/cm ²)		340	fracture strain rate 0.017
Bending strength (kg/cm ²)		400	
Modulus of Elasticity	Compression (kg/cm ²)	74,000	
	Tension (kg/cm ²)	34,000	
Poisson's ratio	Compression	0.34	
	Tension	0.22	
Fracture strain rate	Compression	0.020	0.017 - 0.037
	Tension	0.010	0.010 - 0.014
Coefficient of thermal expansion		6.5×10^{-6}	
Weatherability	Cured in the water	Substantially not affected	For 3 months
	Exposed to the air	Substantially not affected	For 3 months
Chemical resistance		Strong resistance to acid and alkali	

As shown in table 1, the compression strength and tensile strength of the fiber reinforced epoxy panel is higher than those of concrete and the bending strength is also relatively high.

It was found from the specimens cured in the water and in the air at a low temperature that the properties of the epoxy resin product in accordance with the present invention

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were not affected by the weather conditions such as temperature and humidity, and the period disposed in the water. The epoxy resin product also had strong resistance to the acids and alkalis. It was thus proved that the epoxy resin product was appropriate to use in places under severe condition such as seawater, sewage and exhaust gas of vehicles.

Example 2

10 A mold having a size of 800 mm X 1500 mm X 11 mm was prepared. A release agent was applied to inner surfaces of the mold. At least three layers of fiber mesh were arranged in the mold. Thereafter, an epoxy resin mixture including 23.9 wt% of epoxy resin, 1.5 wt% of cement, 74.5 wt% of silica and 0.1 wt% of chopped fibers was cast into the mold and then the mold was vibrated. After hardening process at a temperature of 60°C for 30 minutes, the epoxy resin mixture was pressurized with a load of 1,000 kg. The epoxy resin mixture was further hardened at a temperature of 80°C for 3 hours and then released from the mold. The hardened epoxy resin mixture was cured at a temperature of 25 to 30°C and a humidity of 40 to 50% for 3 days. Properties of finished epoxy resin panels were tested and the results were substantially same as those in Table 1.

Example 3

A steel mold having a size of 170 mm X 150 mm X 1000 mm was prepared. A release agent, e.g., 700-NC or PS-100, was applied to inner surfaces of the mold. Layers of fiber mesh were arranged in the mold. Thereafter, an epoxy resin mixture including epoxy resin, silica, reinforcing fiber, rubbles, cement and inorganic materials was cast into the mold and then air bubbles were removed from the mold. The remaining amounts of the air bobbles were below 4%. The epoxy resin mixture was pressurized with a load of 800 to 1,000 kg and hardened for 1 to 3 hours and then released from the mold. The hardened epoxy resin mixture was cured at a temperature of 25 to 30°C and a humidity of 40 to 50% for 24 hours. The properties of the finished epoxy resin vehicle blocks were tested and a result obtained is as followings:

TABLE 2

Properties		Test results	Concrete
Compression strength (kg/cm ²)		1128	300
Direct tensile strength (kg/cm ²)		360	340
Bending strength (kg/cm ²)		450	400
Weatherability	Cured in the water	Substantially not affected	Affected
	Exposed to the air	Substantially not affected	Affected
Chemical resistance		Strong resistance to acid and alkali	Weak

As shown in Table 2, the compression strength and tensile strength of fiber reinforced epoxy resin vehicle block are higher than those of concrete and the bending strength is also relatively high. Also, the durability was better than that of concrete. It was found from the specimens cured in the water and in the air at a low temperature that the properties of the epoxy resin product in accordance with the present invention were not affected by the weather conditions such as temperature and humidity, and the period disposed in the water. The epoxy resin product also had strong resistance to the acids and alkalis. It was thus proved that the epoxy resin product was appropriate to use in places under severe condition such as seawater, sewage and exhaust gas of vehicles.

While the invention has been shown and described with respect to the preferred embodiments, it will be understood by those skilled in the art that various changes and modifications may be made without departing from the spirit and scope of the invention as defined in the following claims.